Update on the VIIRS+CrIS fusion radiance product (VIIRS+CrIS Fusion Moisture Product)

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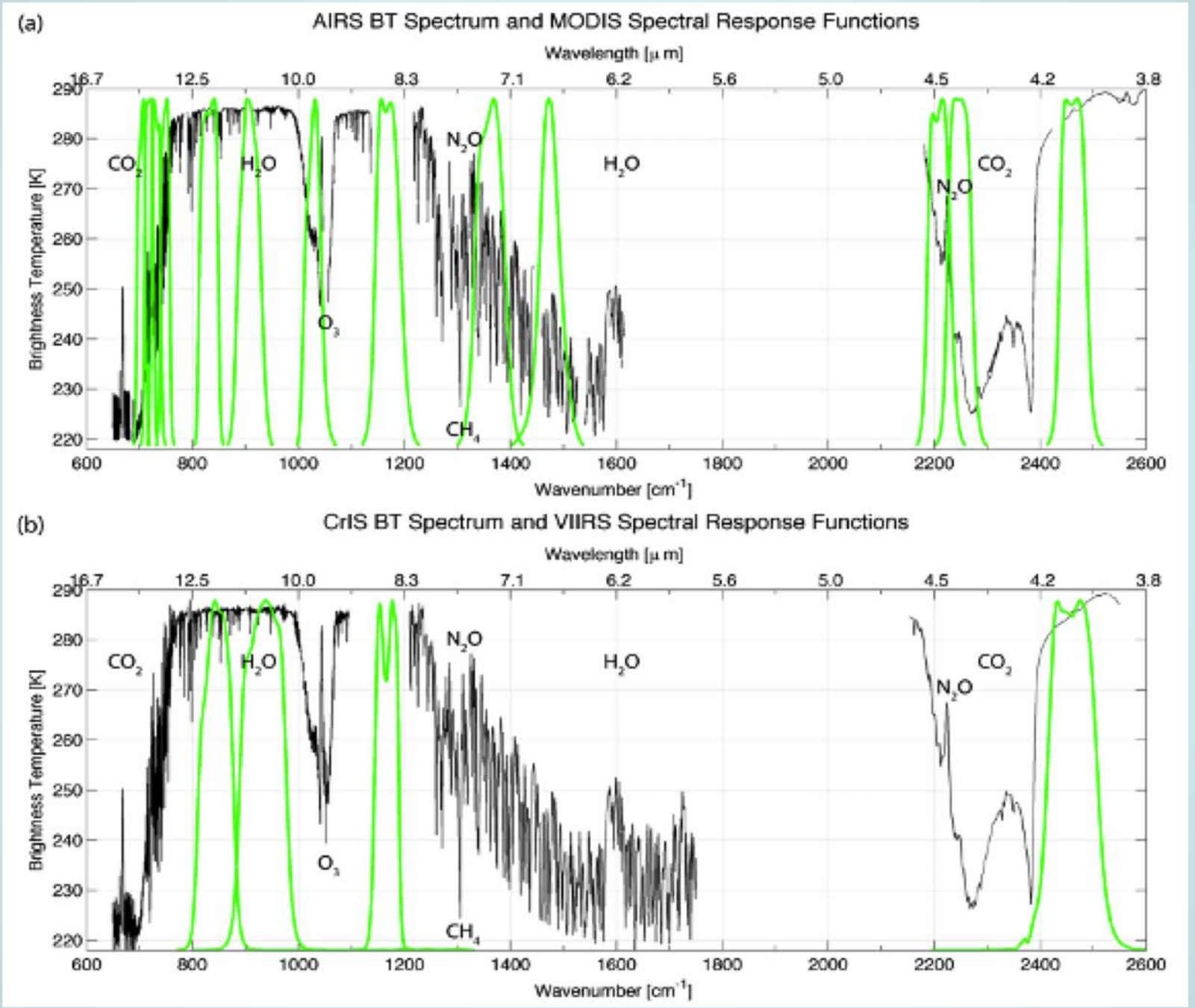
May 13, 2021


(a)
AIRS BT Spectrum and MODIS Spectral Response Functions
Wavelength [μ m]
16.7
12.5
10.0
8.3
7.1
6.2
5.6
5.0
4.5
4.2
3.8
Brightness Temperature [K]
290
280
270
260
250
240
230
220
CO2
H2O
O3
N2O
CH4
H2O
N2O
CO2
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
Wavenumber [cm-1]
(b)
CrIS BT Spectrum and VIIRS Spectral Response Functions
Wavelength [μ m]
16.7
12.5
10.0
8.3
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6.2
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600
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1800
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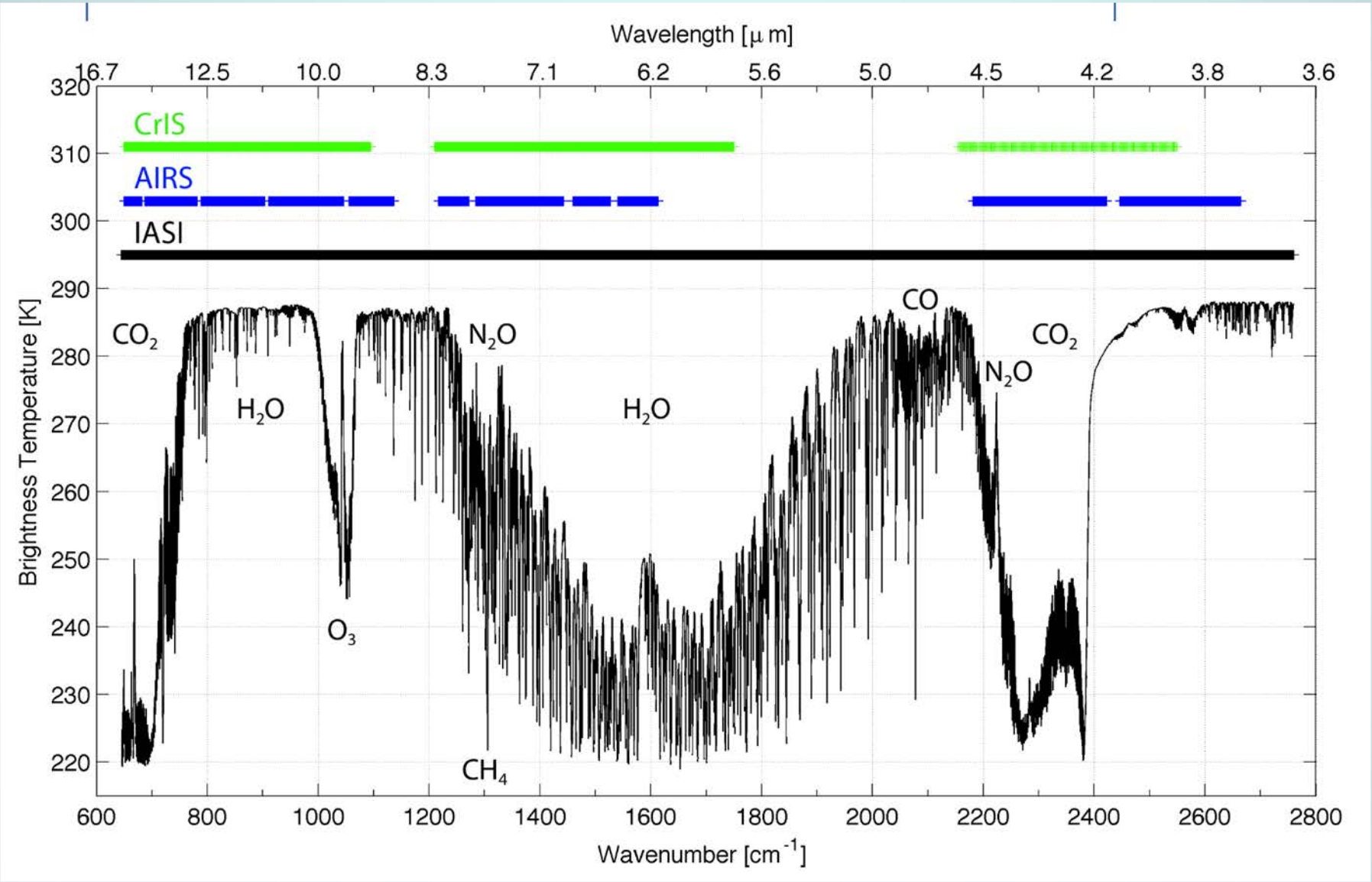
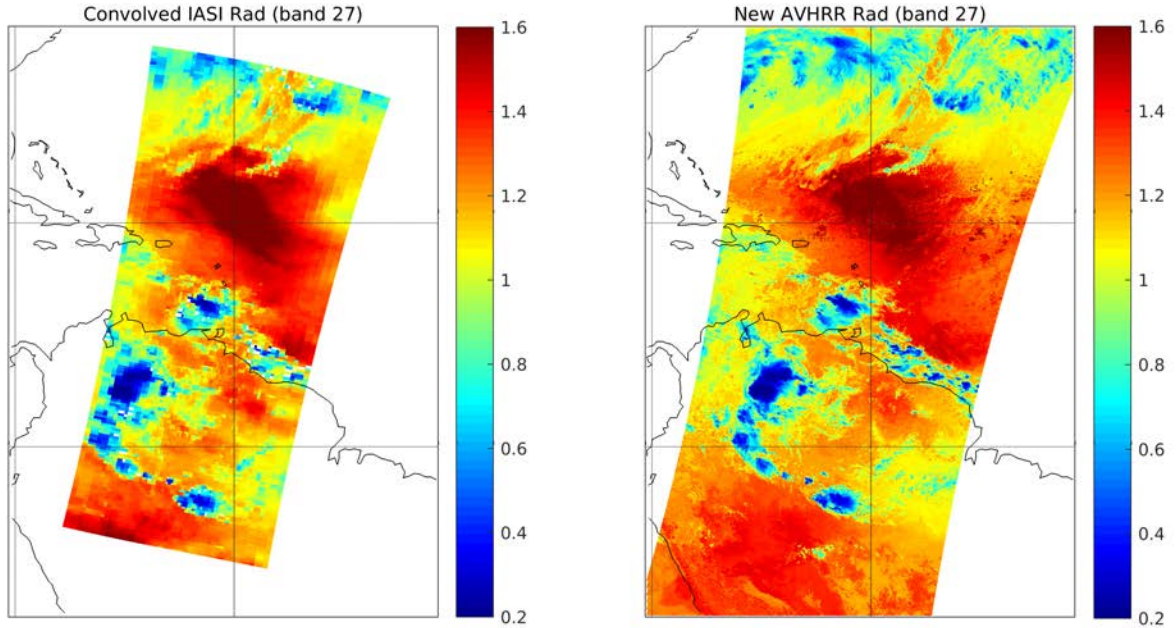
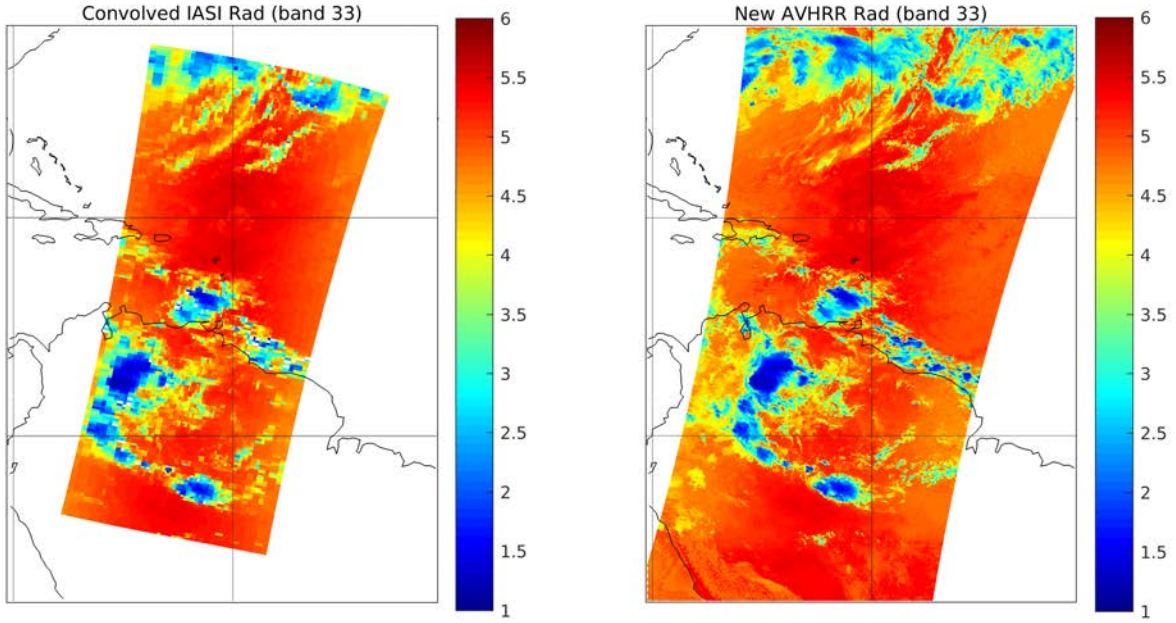
2200
2400
2600
Wavenumber [cm-1]

Option for construction of fusion narrowband/broadband channels for MetOP





Fusion 6.7-μm AVHRR channel



Fusion 13.3-μm AVHRR channel

Could also construct broadband channel(s) defined in Fu-Liou/RRTMG codes

Where we are…

1. Version 1.01 is the current operational version (available at LAADS); both VIIRS and CrIS Level-1b calibration is Version 2.x.

2. A development version of fusion running in forward stream, currently 1.1x; both VIIRS and CrIS calibration is Version 3.x (plus other changes to be discussed). Once this development version is frozen, it will be labeled Version 2 and will remain unchanged unless something happens that impacts the product's viability. Users will be contacted immediately.

3. Established relationship with VIIRS/CrIS calibration teams – this has developed into a 2-way dialogue. Good news is that data gaps are now filled in as much as possible, including:

- WUCD (warm-up, cool-down) calibration periods although this impacts S-NPP more than NOAA-20. Not much changed for NOAA-20
- Granules impacted by lunar calibration
- Not sure yet how inter-platform MODIS-VIIRS sensor calibration will play out

Fusion Version 2

Both V2 and CERES subsetter code has been delivered to Atmosphere SIPS

The working plan is as follows:

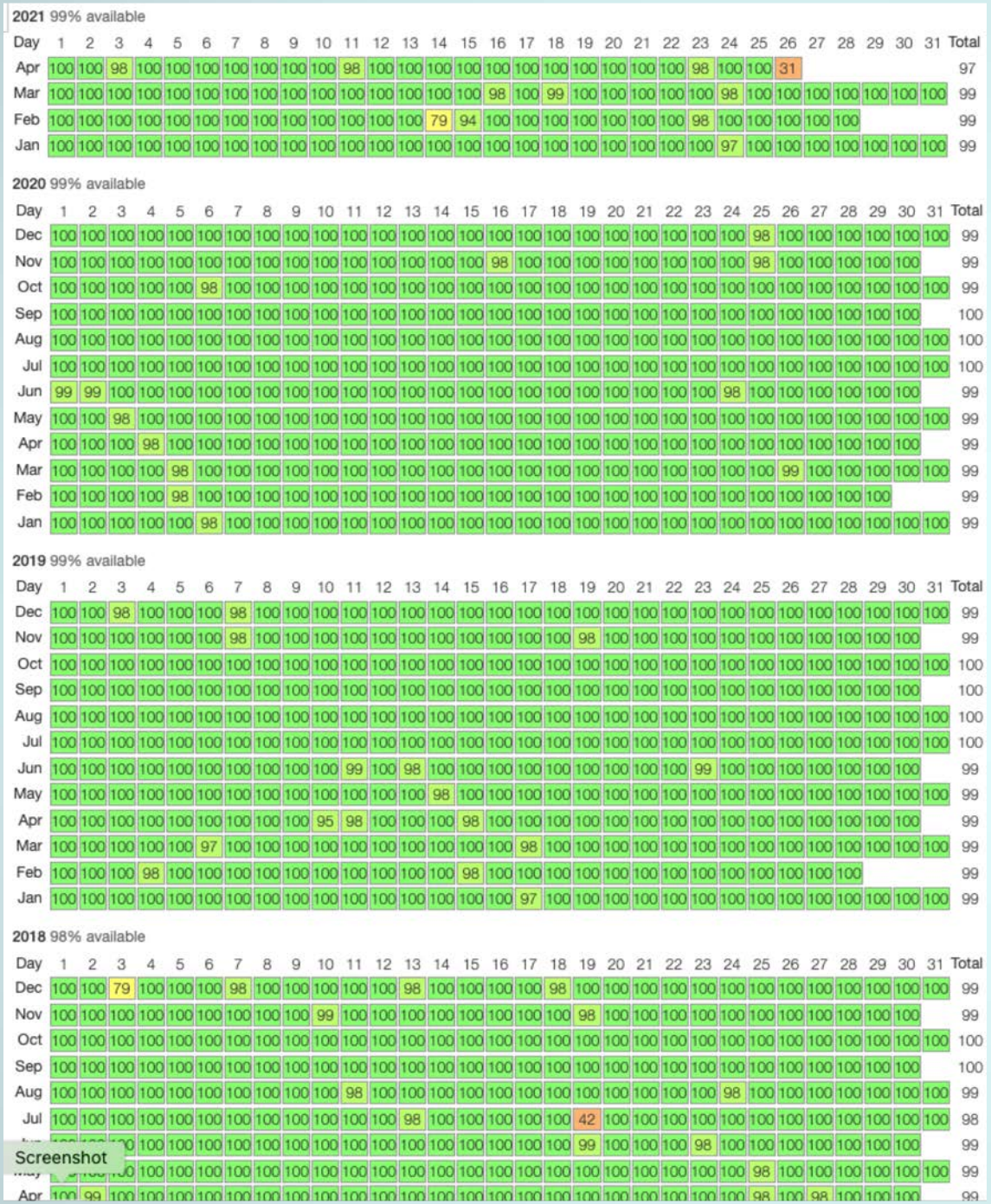
- generate 2 months of test data plus selected days
- implement in forward stream
- go back and generate entire record, beginning with NOAA-20

Two items that are holding up the process (maybe another week)

- updated VIIRS-CrIS colocation package (Eva found some issues)
- new VIIRS Level-1b LUT

Currently looking at about 4-6 weeks for things to really get moving. In the past, this process has been quick; it’s not our first time doing this.

As things currently stand, CERES will be pulling a subset of Version 2 fusion radiances. A new CERES subsetter is now part of the package.



2021 99% available

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Apr	100	100	98	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	98	100	100	31						97
Mar	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	99	100	100	100	100	100	98	100	100	100	100	100	100	100	99
Feb	100	100	100	100	100	100	100	100	100	100	100	100	100	79	94	100	100	100	100	100	100	100	98	100	100	100	100	100				99
Jan	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	100	100	100	100	100	100	100	99

2020 99% available

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Dec	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	99
Nov	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	98	100	100	100	100	100		99
Oct	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99
Sep	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		100
Aug	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Jul	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Jun	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100		99
May	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99
Apr	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		99
Mar	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	99
Feb	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100			99
Jan	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99

2019 99% available

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Dec	100	100	98	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99
Nov	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100		99
Oct	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sep	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		100
Aug	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Jul	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Jun	100	100	100	100	100	100	100	100	100	100	99	100	98	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100		99
May	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99
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Mar	100	100	100	100	100	97	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99
Feb	100	100	100	98	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100				99
Jan	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	97	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99

2018 98% available

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
Dec	100	100	79	100	100	100	98	100	100	100	100	100	98	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	100	99
Nov	100	100	100	100	100	100	100	100	100	99	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100		99
Oct	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Sep	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		100
Aug	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	100	99
Jul	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	42	100	100	100	100	100	100	100	100	100	100	100	100	98
				100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	99	100	100	100	98	100	100	100	100	100	100	100		99
				100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	100	100	100	100	100	99
Apr	100	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100	98	100	100	100		99

Screenshot

NOAA-20 Fusion

Production Stats

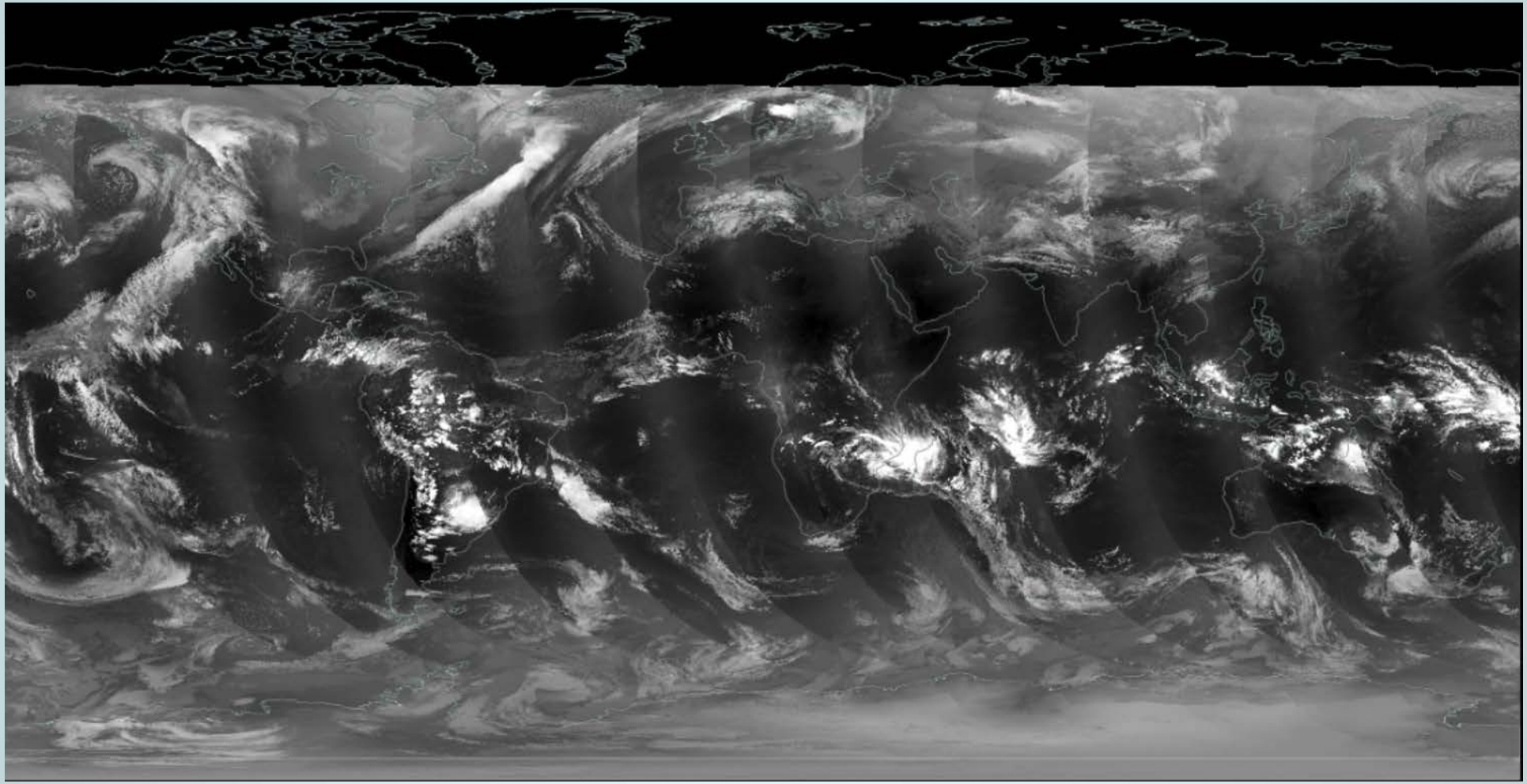
Version 1.01

(will be updated for Version 2)

Legend

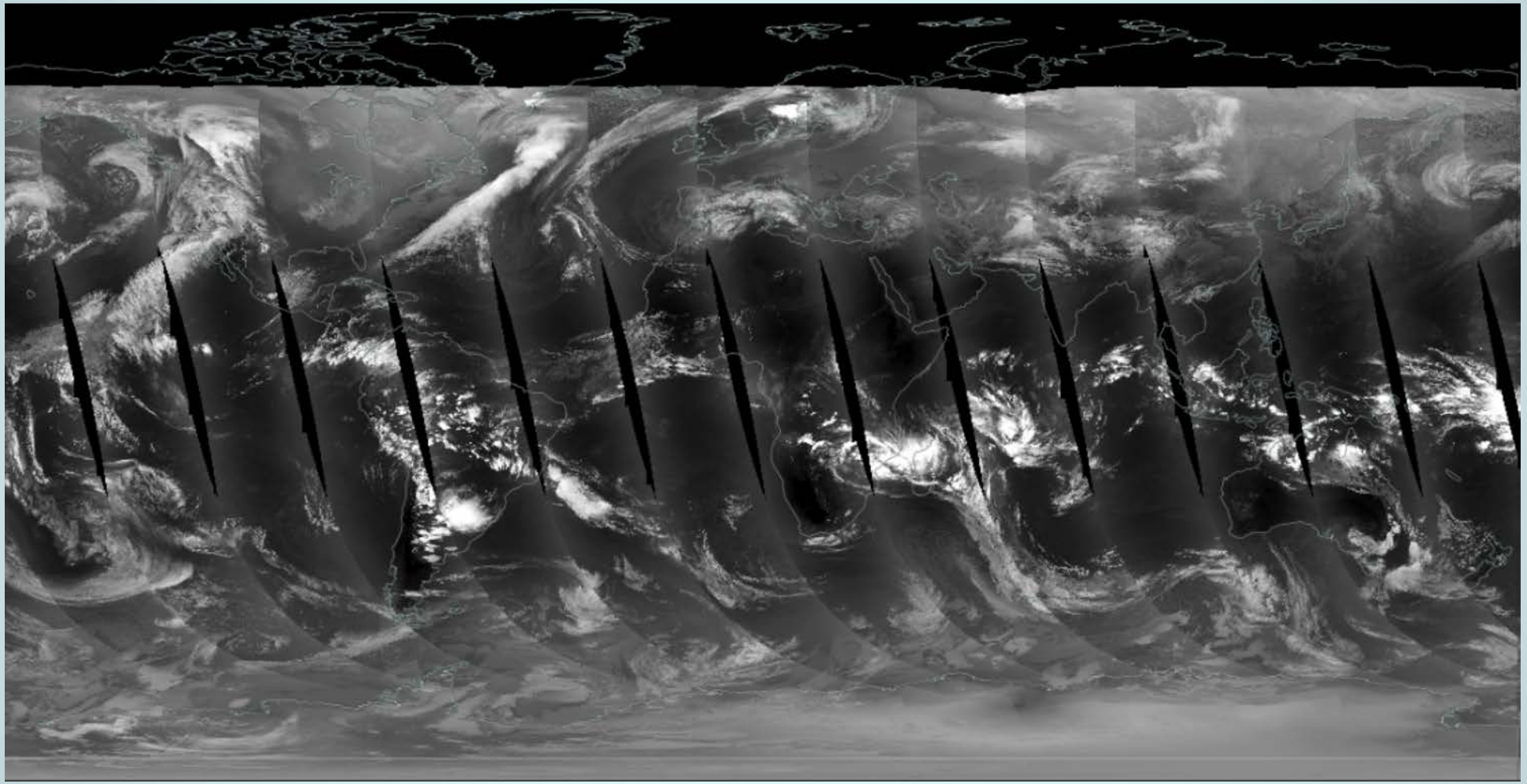
- 100%
- 90 to 99%
- 50 to 89%
- 1 to 49%
- No data

Worldview: NOAA-20 VIIRS+CrIS Fusion 13.3-μm Channel Daytime
Version 1.1.x (development version)



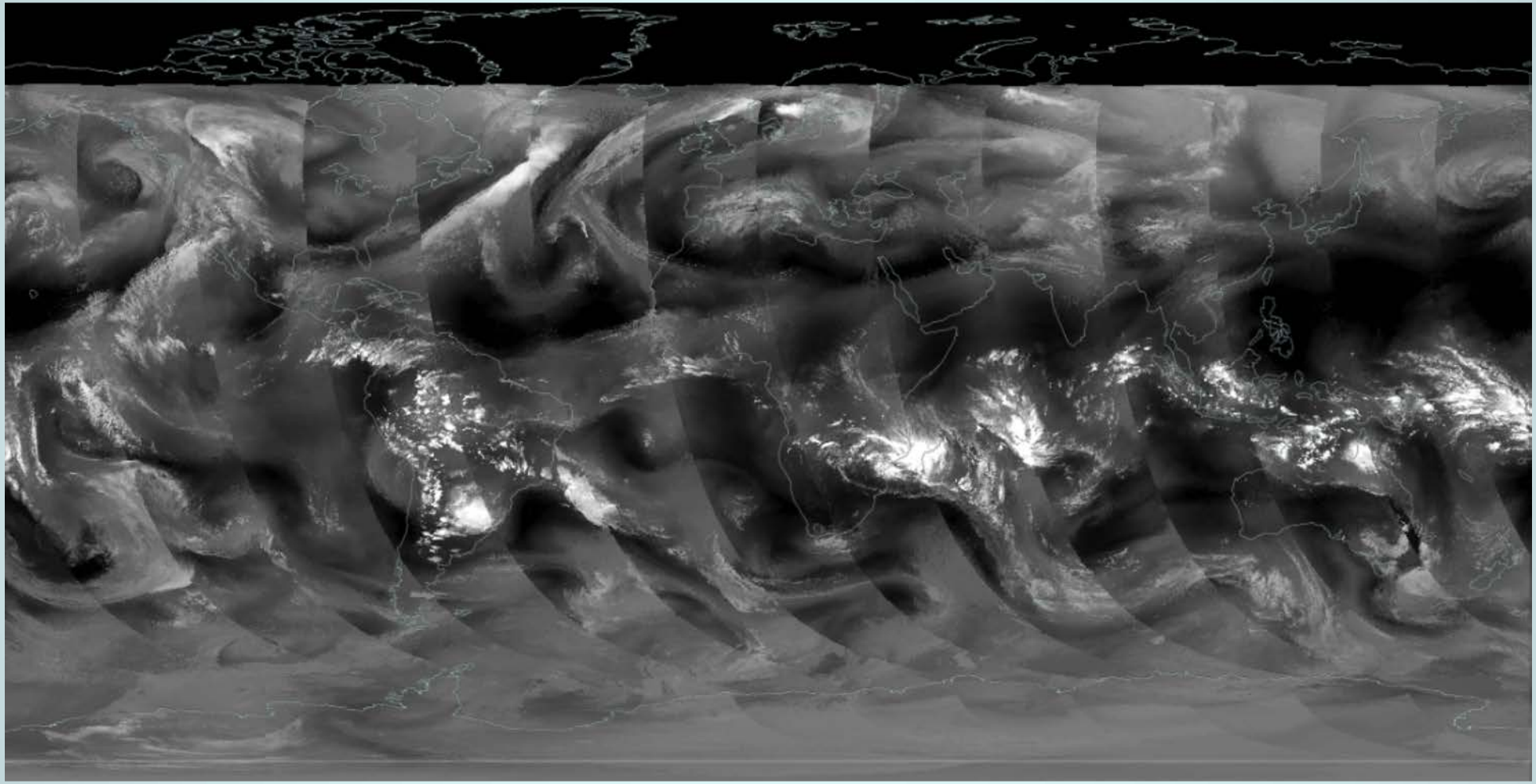
January 20, 2020

Worldview: Aqua MODIS 13.3-μm Channel
Daytime



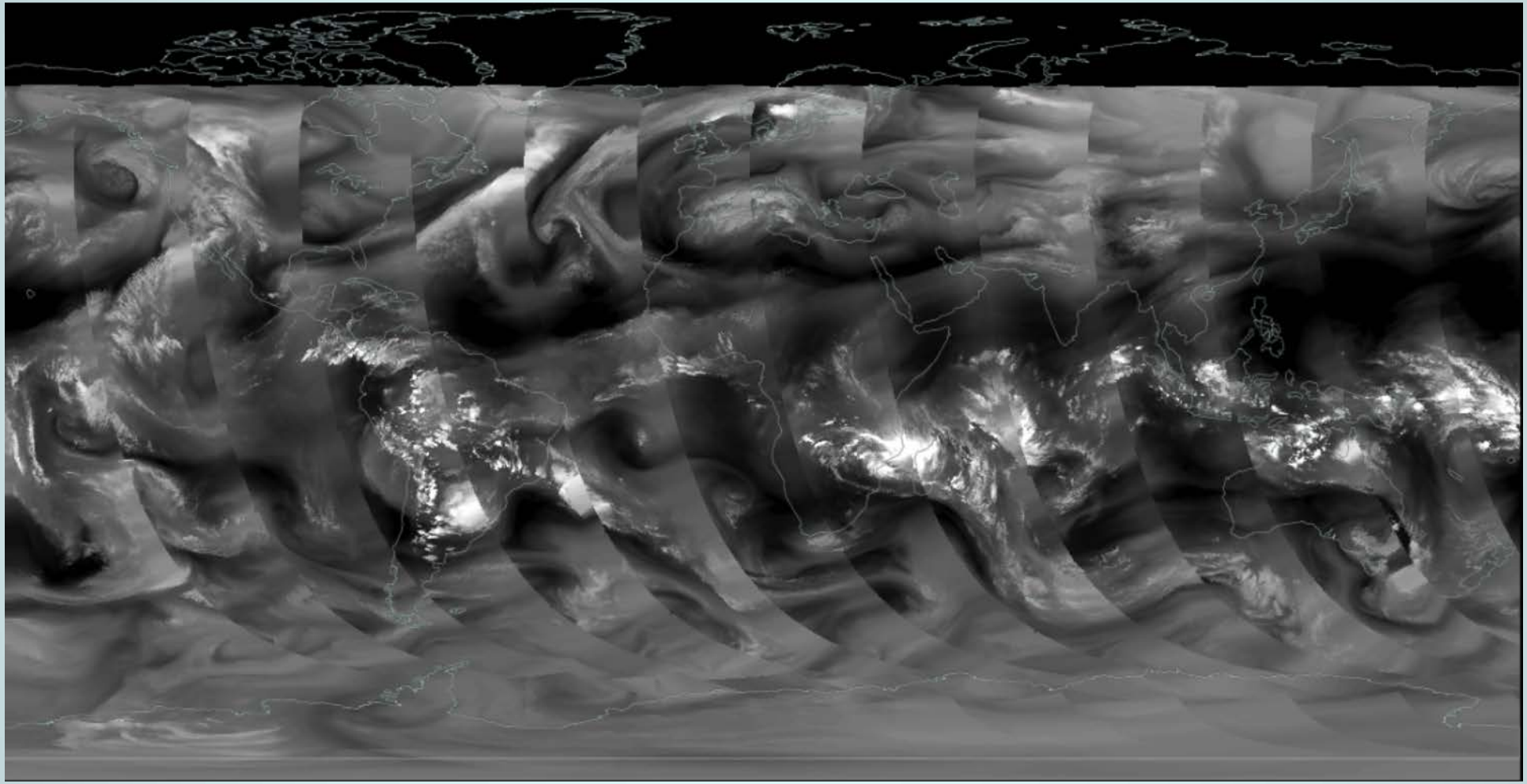
January 20, 2020

Worldview: NOAA-20 VIIRS+CrIS Fusion 6.7-µm Channel Daytime Version 1.0.1



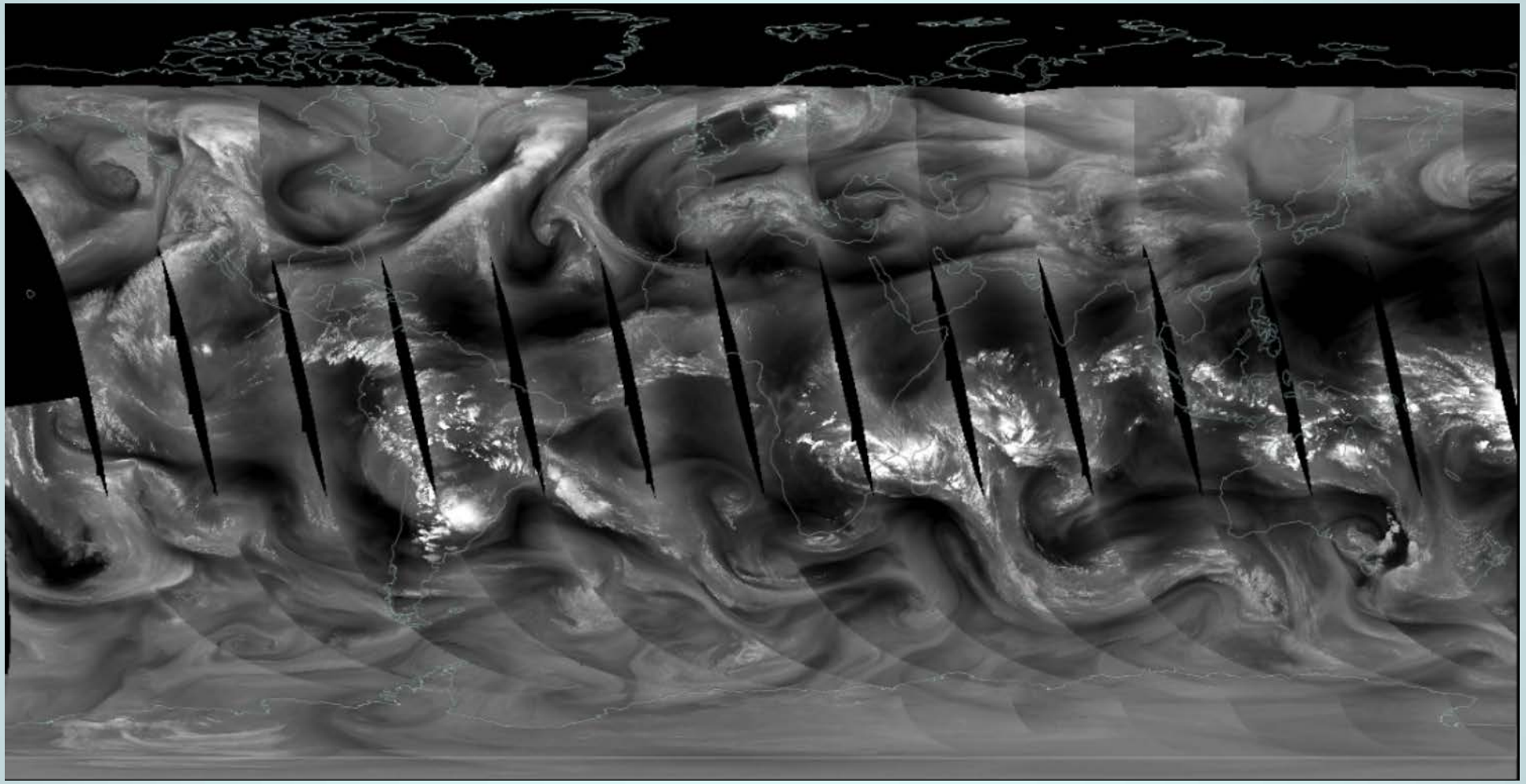
January 20, 2020

Worldview: NOAA-20 VIIRS+CrIS Fusion 6.7-μm Channel Daytime
Version 1.1.x (development version)



January 20, 2020

Worldview: Aqua MODIS 6.7-μm Channel Daytime



January 20, 2020

Summary

What will be implemented in Version 2:

1. Updates include VIIRS & CrIS calibration, collocation, and methodology.

2. Established relationship with VIIRS/CrIS calibration teams
    - filled in data gaps as much as possible
    - filling in, as much as possible, through WUCD (warm-up, cool-down) calibration periods although this impacts S-NPP more than NOAA-20

3. Implemented final improvements for the water vapor channels (27 and 28)

4. Software submitted to the A-SIPS/LAADS; updated User's Guide and ATBD

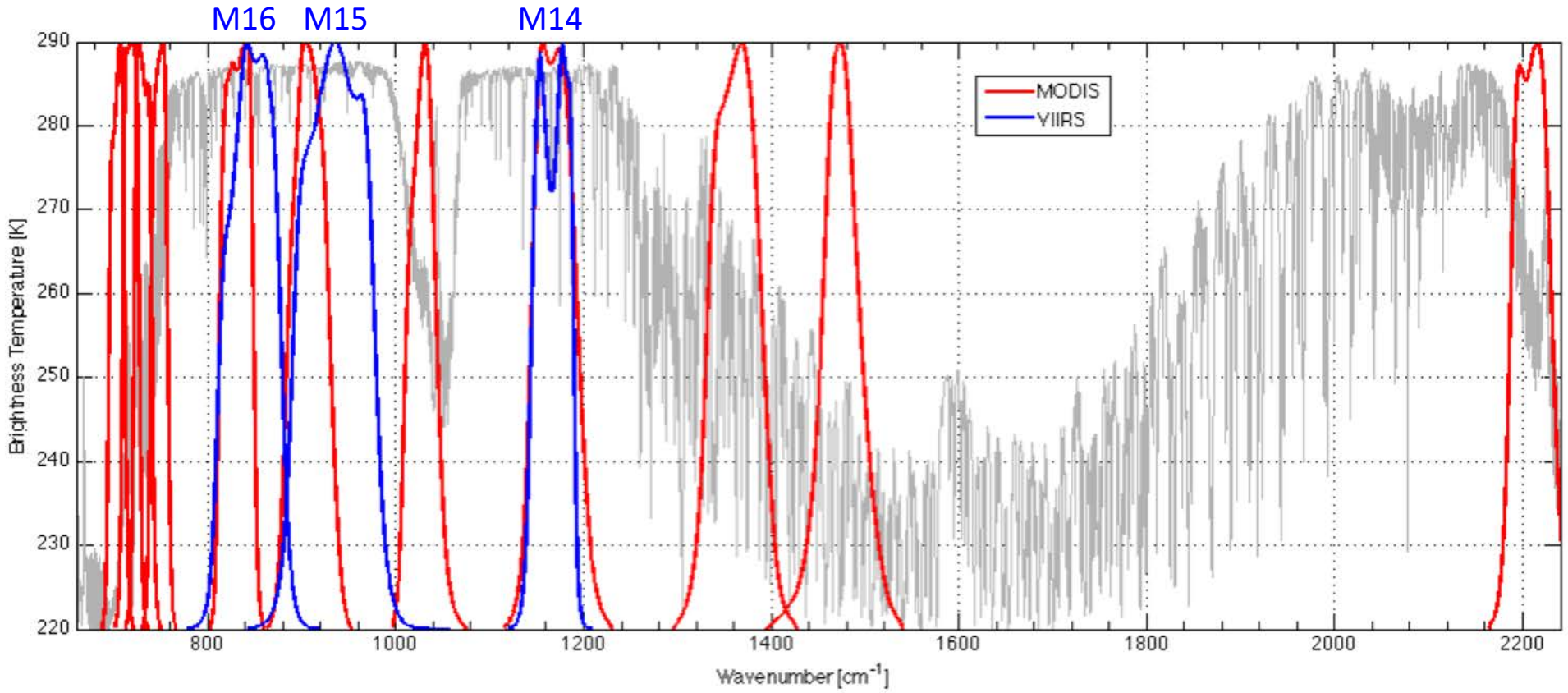
Improvement in Tropospheric Moisture Retrievals from VIIRS through VIIRS and CrIS Data Fusion

Éva Borbás, Elisabeth Weisz, Chris Moeller, Paul Menzel
UW-Madison, Space Science and Engineering Center
Bryan Baum – *Science and Technology Corporation*
Geoff Cureton, and Ethan Nelson – *NASA Atmosphere-SIPS*

MOTIVATION: to work towards continuity of moisture products from Terra and Aqua, Suomi-NPP (henceforth S-NPP), NOAA-20, and the subsequent JPSS platforms.

CHALLENGE: The absence of water vapor and CO_2 absorption IR spectral bands on the VIIRS imager on the Suomi-NPP and NOAA-20 polar-orbiting platforms limits the capability for tropospheric moisture retrievals, especially for upper tropospheric humidity.

Spectral Response Functions of Aqua/MODIS TIR and VIIRS bands used by the Moisture algorithm



Official Moisture Products:

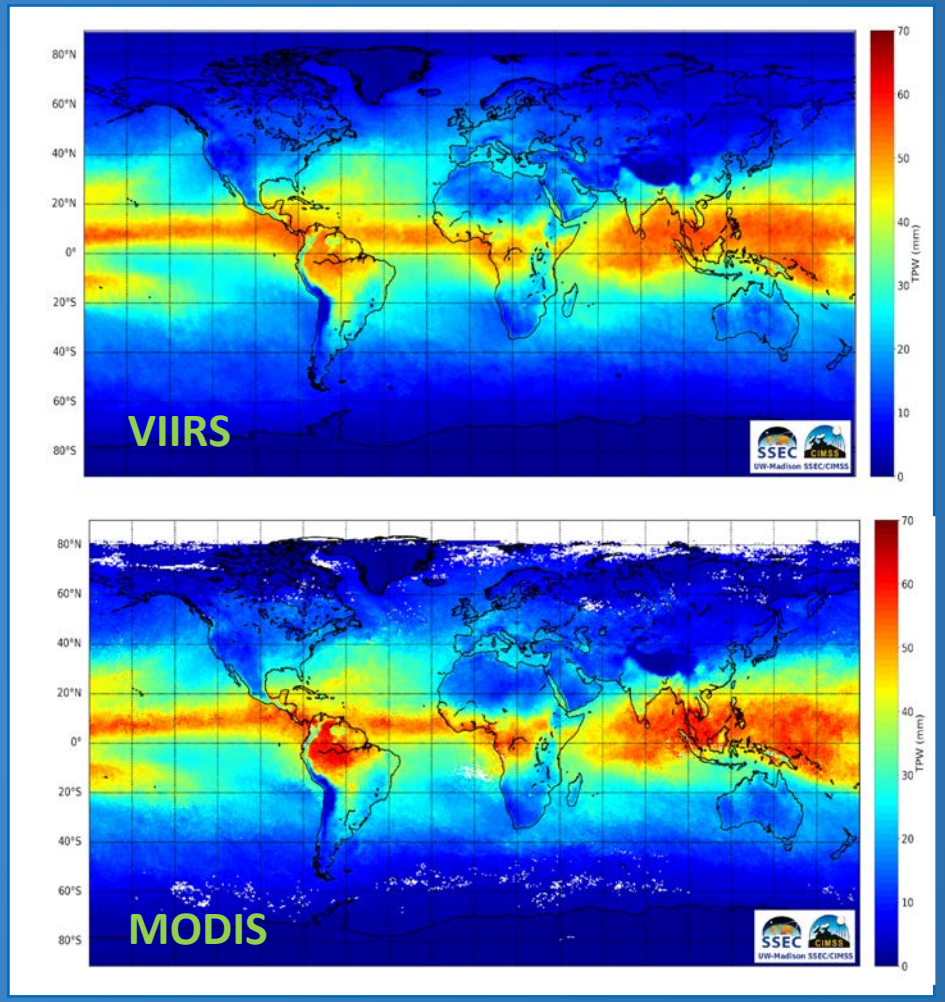
MODIS Atmospheric Profile Products (MOD07, MYD07)

- DOI: 10.5067/MODIS/MOD07_L2.061,
- DOI: 10.5067/MODIS/MOD08_D3.061
- DOI: 10.5067/MODIS/MOD08_M3.061

VIIRS Water Vapor Products (WATVP VIIRS)

- DOI: 10.5067/VIIRS/WATVP_L2_VIIRS_SNPP.001
- DOI: 10.5067/VIIRS/WATVP_D3_VIIRS_SNPP.001
- DOI: 10.5067/VIIRS/WATVP_M3_VIIRS_SNPP.001

- Clear sky Retrievals over land/ocean and day/night
- Advantage is the high spatial resolution
- Statistical Regression Algorithm
- Using CRTM/RTTOV Forward Model and
- SeeBor Global training dataset with CAMEL V1.0 Land Surface emissivity
- **Uncertainty**: MOD07 TPW within 2 (3.2) mm rms for dry (wet) retrievals wrt Microwave Water Vapor Radiometer (at SGP Cart site)



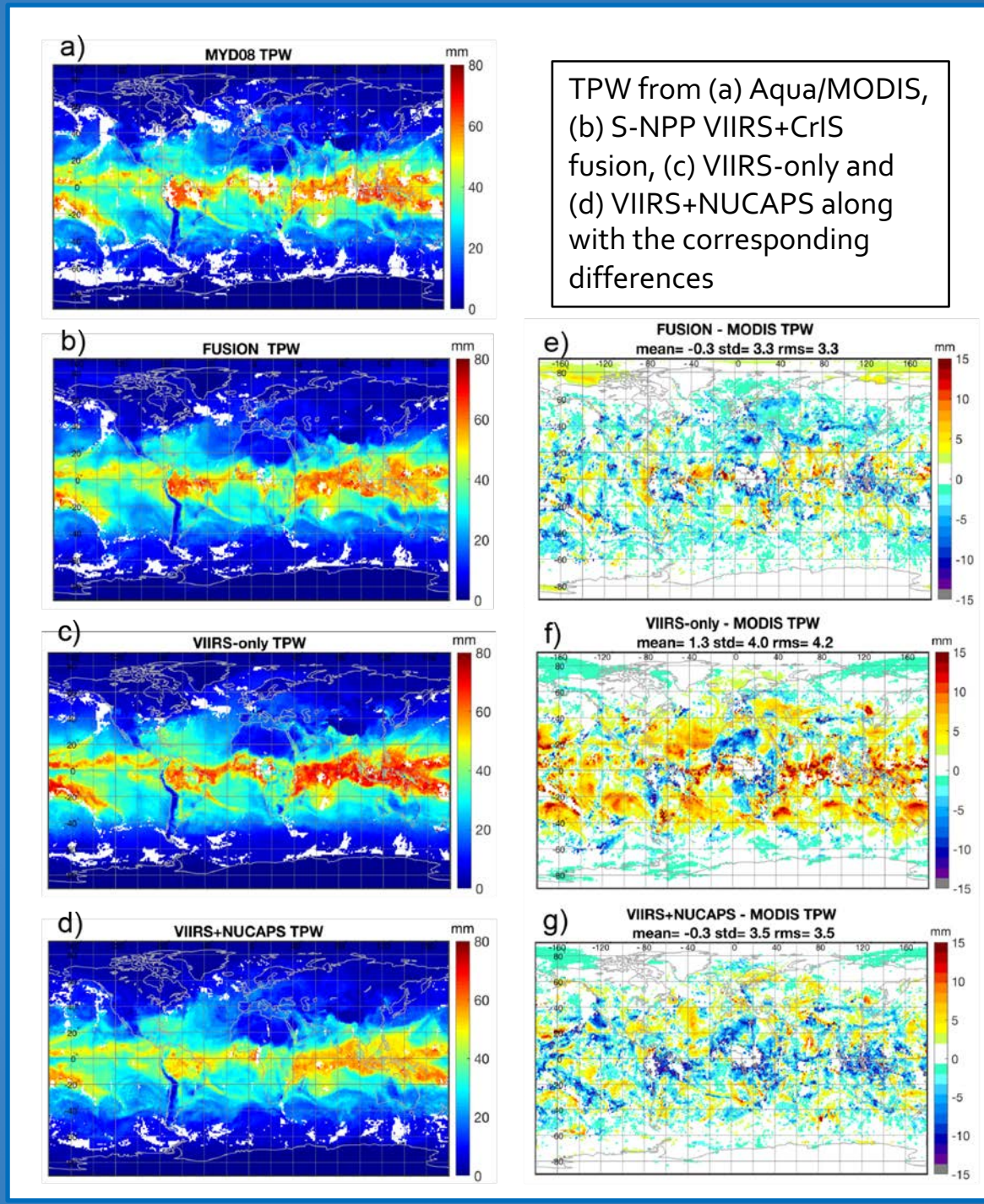
Monthly (Oct 2014) mean 0.5 degree gridded VIIRS+NUCAPS (left) and AQUA/MODIS (right) TPW products.

Comparison of the MODIS and the VIIRS TPW Products

Characteristics	MODIS (MOD07)	VIIRS (Version1)	VIIRS Fusion (Future Version 2)
Spectral Bands	IR CO_2, H_2O and IRW bands (11 bands)	VIIRS Band: M14, M15, M16 NUCAPS TPW	MODIS-like VIIRS+CrIS Fusion Bands (11 bands)
Spatial Resolution	5km : 5x5 1km average	750m average	750m average
Outputs	TPW 3 layers of Integrated WV (inc/. UTH) Surface Temperature Temperature, Mixing Ratio Profile Total Ozone Stability indices (LI, K, TT)	TPW Sfc Temperature	TPW 3 layers of Integrated WV (incl. UTH) Surface Temperature Temperature, Mixing Ratio Profile Total Ozone Stability indices (LI, K, TT)

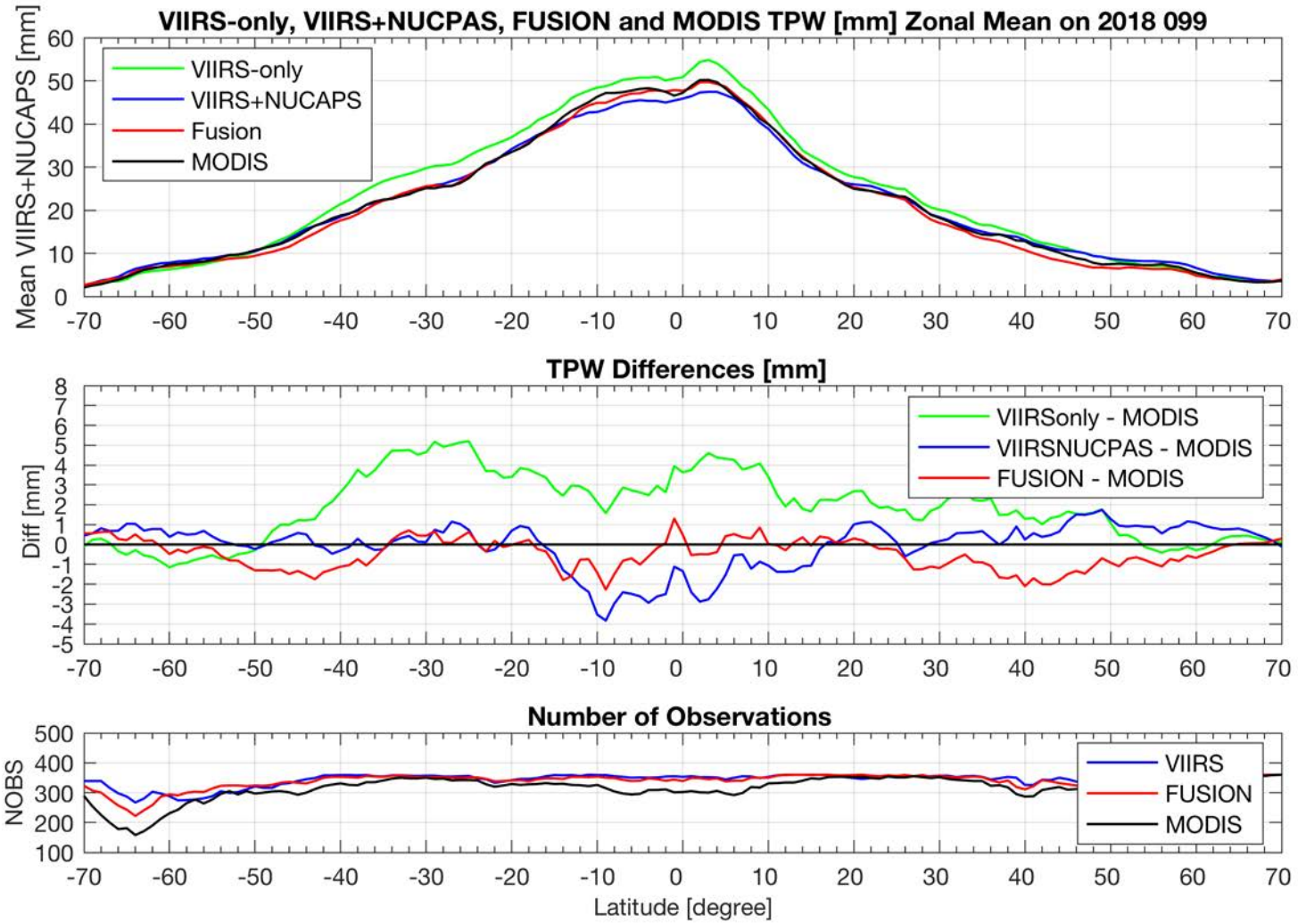
Global comparisons of the VIIRS TPW products to the MODIS Col 6.1 moisture products on April 9, 2018

- The VIIRS+CrIS fusion TPW best fit to the MODIS TPW with - 0.3 mm (too low) bias and scatter of 3.3 mm.
- TPW results are similar for a month in each season of 2017 (e.g. Jan, Apr, Jul, and Oct).



TPW from (a) Aqua/MODIS, (b) S-NPP VIIRS+CrIS fusion, (c) VIIRS-only and (d) VIIRS+NUCAPS along with the corresponding differences

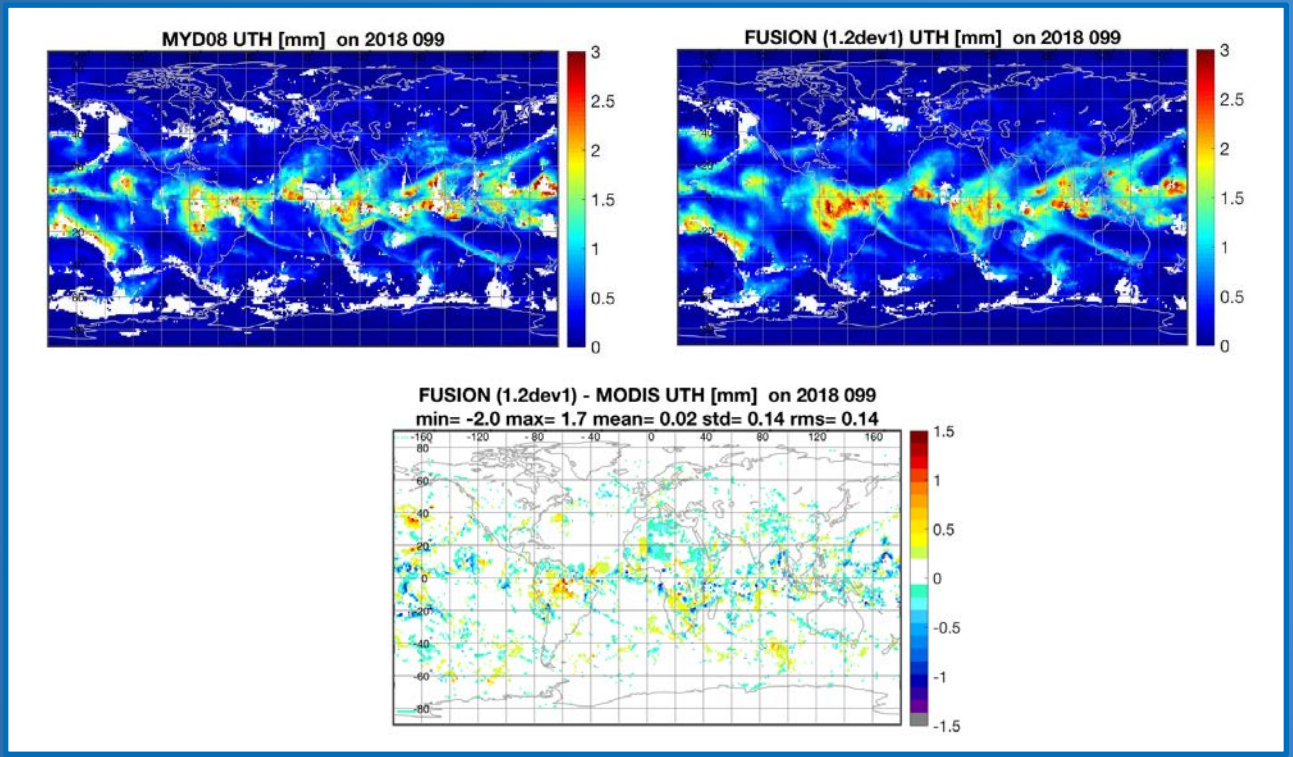
Latitudinal distribution of TPW and their differences for April 9, 2018



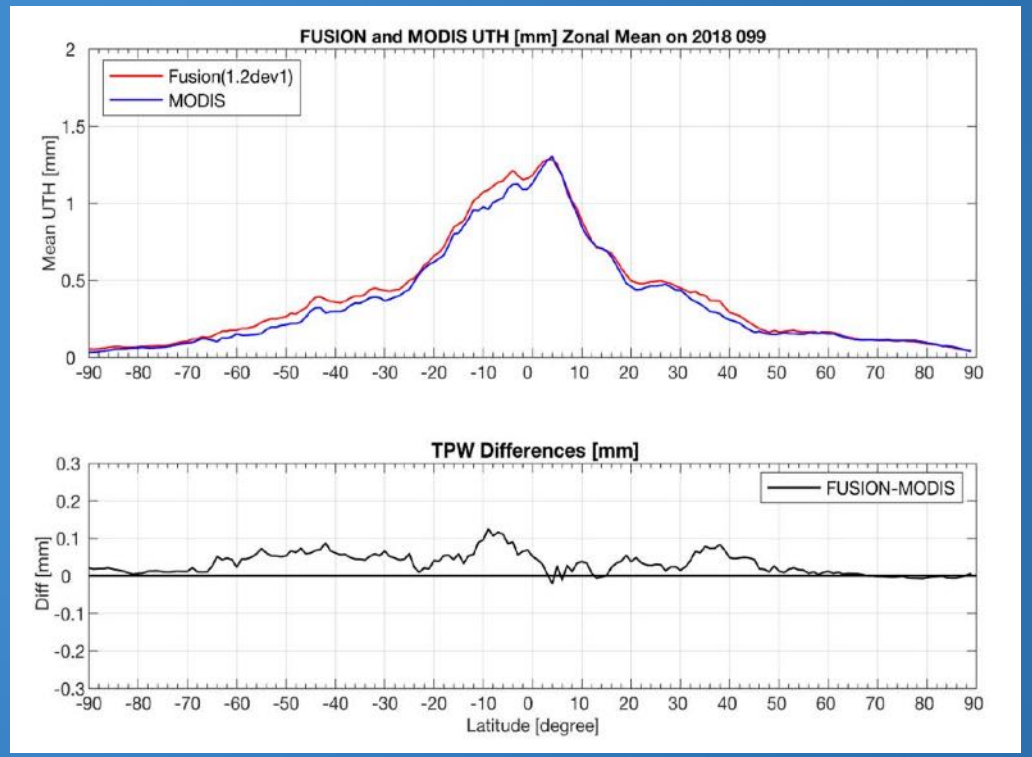
Over the tropics, where the highest moisture levels occur, the VIIRS+CrIS fusion product agrees more closely with the MODIS than the VIIRS+NUCAPS, which mostly underestimates the water vapor content.

Upper Tropospheric Humidity

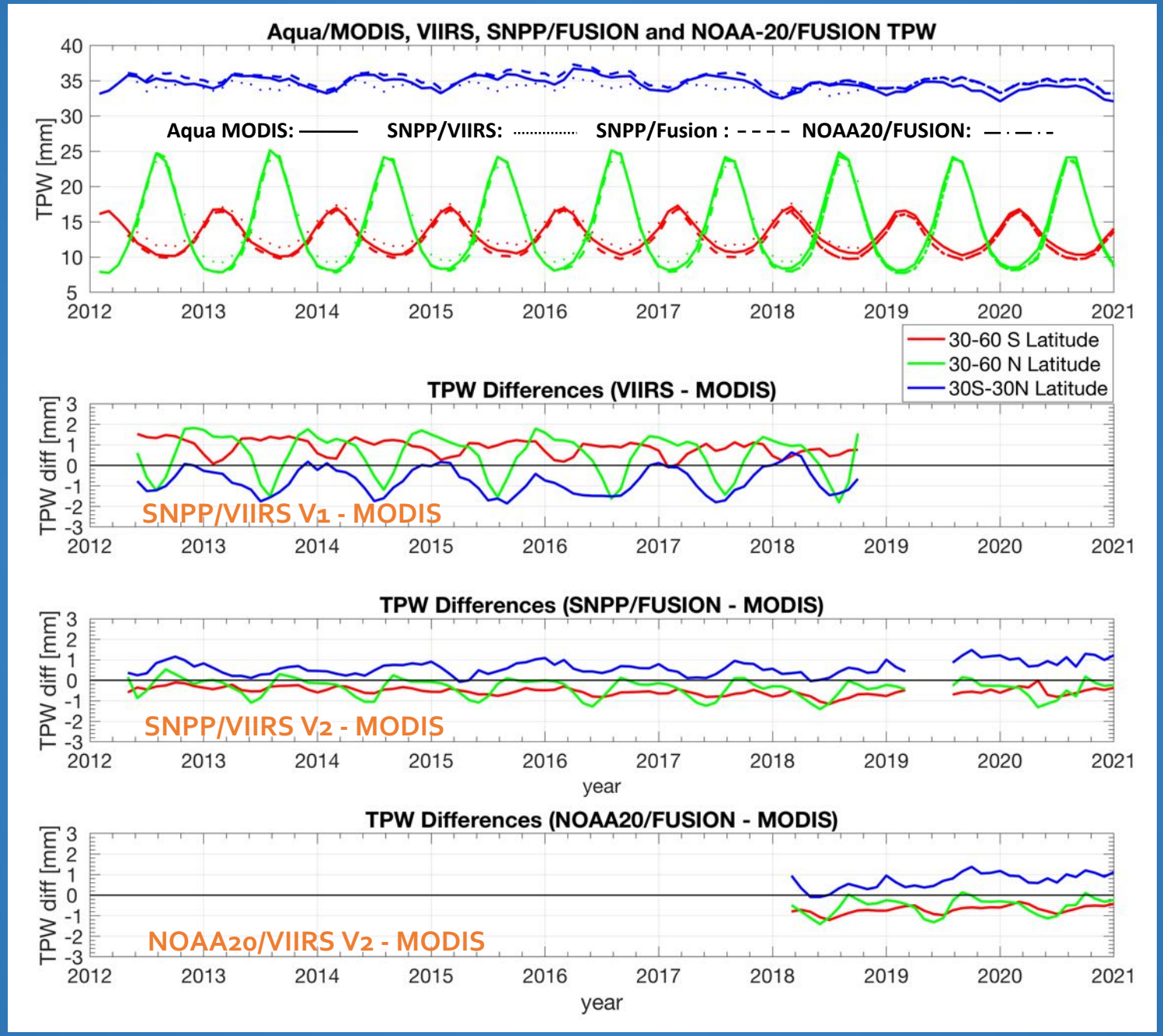
- Without the fusion radiances, VIIRS has little or no sensitivity to UTH.
- Operational VIIRS moisture products do not currently include the UTH product
- Overall, the results are typically within 10% of each other and accurate enough to determine daily and seasonal variability.



Geographical distribution of UTH [mm] results derived from the MODIS MYD08, and VIIRS+CrIS fusion, and their difference for 9 April 2018.



Latitudinal distribution of UTH [mm] results for MODIS and VIIRS+CrIS fusion on 9 April 2018 data and their corresponding differences.


Aqua/MODIS, VIIRS, SNPP/FUSION and NOAA-20/FUSION TPW
TPW [mm]
Aqua MODIS: ——— SNPP/VIIRS: ····· SNPP/Fusion : - - - - NOAA20/FUSION: — · — · -
30-60 S Latitude
30-60 N Latitude
30S-30N Latitude
TPW Differences (VIIRS - MODIS)
TPW diff [mm]
SNPP/VIIRS V1 - MODIS
TPW Differences (SNPP/FUSION - MODIS)
SNPP/VIIRS V2 - MODIS
year
TPW Differences (NOAA20/FUSION - MODIS)
NOAA20/VIIRS V2 - MODIS
year

Summary

- Fusion TPW matches the MODIS product with better bias and rms than currently official VIIRS Products
- Fusion UTH, now possible with the addition of the fusion radiances, is found to be within 10% of the MODIS UTH in mean and scatter for the same four months.
- Use of the H_2O fusion bands brings fusion products into family with MODIS (three layers of WV, atmospheric profiles etc)
- **These findings demonstrate the potential in the use of fusion IR absorption spectral bands for generating moisture products and continuing the moisture record from MODIS and the previous generations of polar orbiting satellite sensors.**

- **References:**

  - Borbas, E.E., Weisz, E., Moeller, C., Menzel, W.P., Baum, B.A. 2021: Improvement in tropospheric moisture retrievals from VIIRS through the use of infrared absorption bands constructed from VIIRS and CrIS data fusion. *Atmos. Meas. Tech.*, **14**, 1191–1203, https://doi.org/10.5194/amt-14-1191-2021
  - Li, Y., B. A. Baum, A.K. Heidinger, W. P. Menzel, and E. Weisz, 2020: Improvement in cloud retrievals from VIIRS through the use of infrared absorption channels constructed from VIIRS-CrIS data fusion, *Atmos. Meas. Tech.*, **13**, 4035-4059, https://doi.org/10.5194/amt-13-4035-2020.
  - Weisz, E., Baum, B. A., and Menzel, W. P., 2017: Fusion of Satellite-Based Imager and Sounder Data to Construct Supplementary High Spatial Resolution Narrowband IR Radiances, *J. of Applied Remote Sensing*, 11(3), 036022. http://doi.org/10.1117/1.JRS.11.036022, 2017.